Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

August 26th, 2020

(data current to August 25th)

Biocomplexity Institute Technical report: TR 2020-104

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About Us

- Biocomplexity Institute at the University of Virginia
  - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
  - Pandemic response for Influenza, Ebola, Zika, and others

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Overview

- **Goal**: Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
  - Calibrate explanatory mechanistic model to observed cases
  - Project infections through October
  - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
  - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
  - Geographic spread over time, case counts, healthcare burdens

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

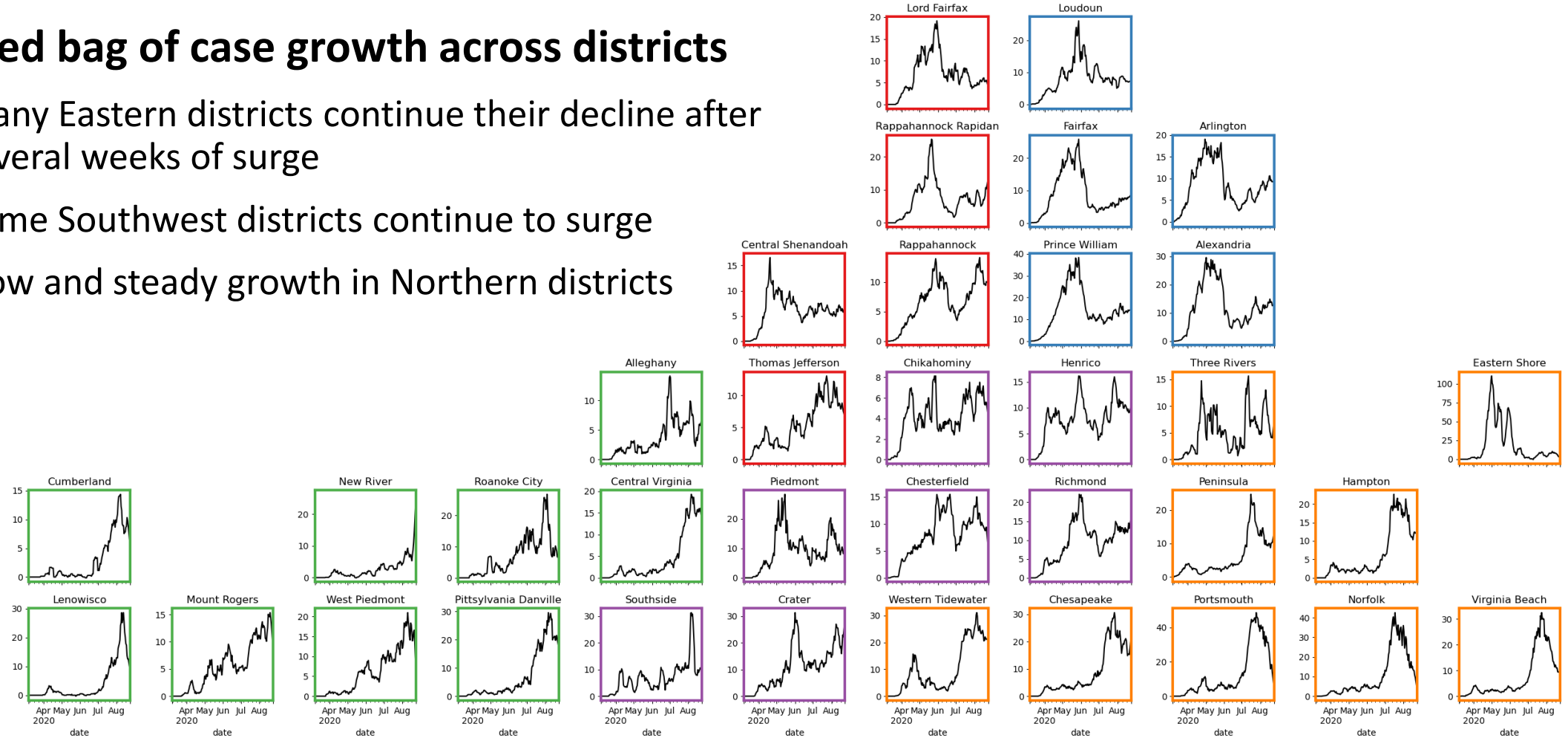
- **Surges are fading and incidence is declining.**
- Majority of districts are plateauing or declining
- Projections are mixed across a range of slow-growth, plateaus, and declines
- Recent model updates:
  - Adaptive Fitting projection remains, slight adjustments to projection filtering
  - Seasonal effects scenarios for planning for end of summer changes
- The situation is changing rapidly. Models will be updated regularly.

Situation Assessment

Case Rate (per 100k) by VDH District

Mixed bag of case growth across districts

- Many Eastern districts continue their decline after several weeks of surge
- Some Southwest districts continue to surge
- Slow and steady growth in Northern districts



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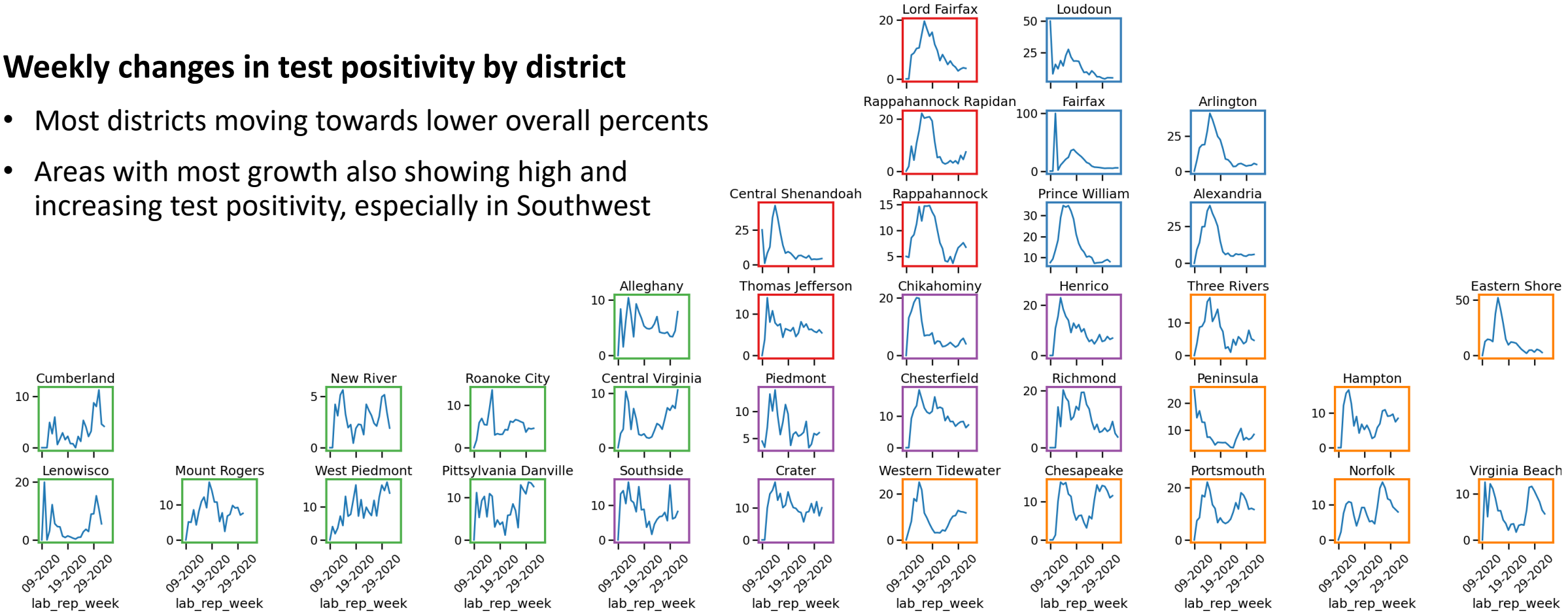
Test Positivity by VDH District

Weekly changes in test positivity by district

- Most districts moving towards lower overall percents
- Areas with most growth also showing high and increasing test positivity, especially in Southwest



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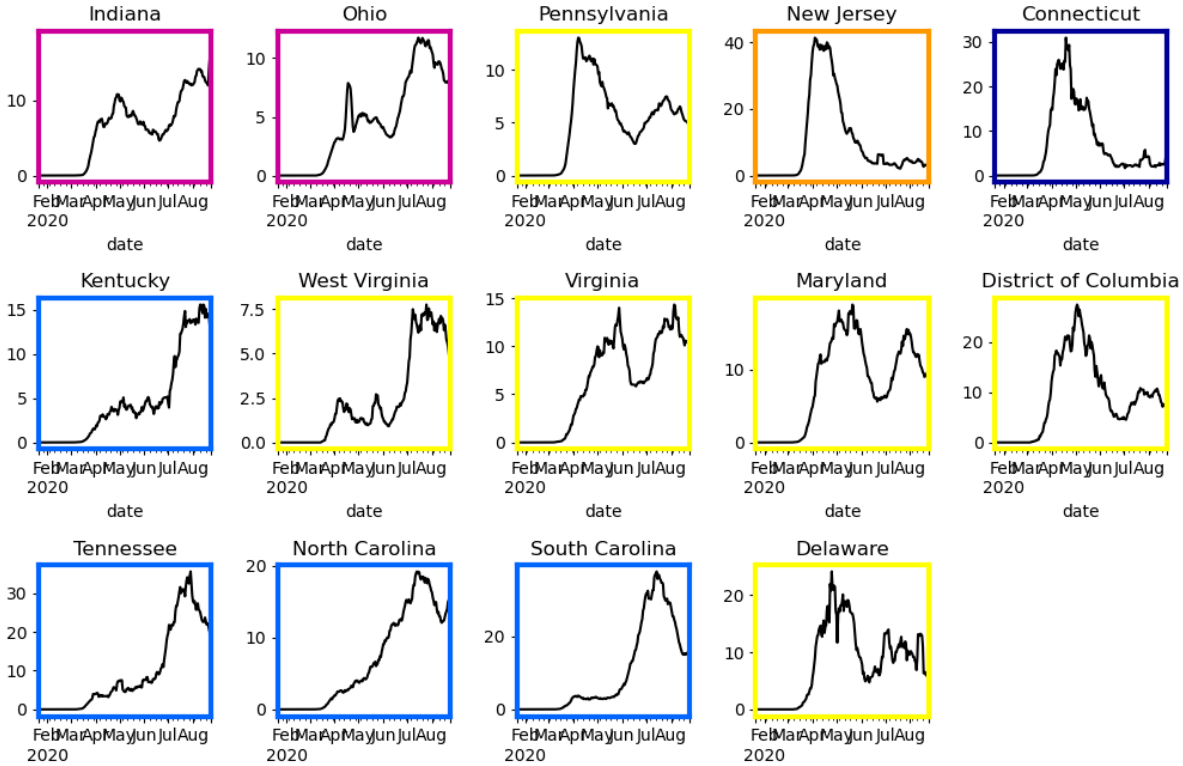
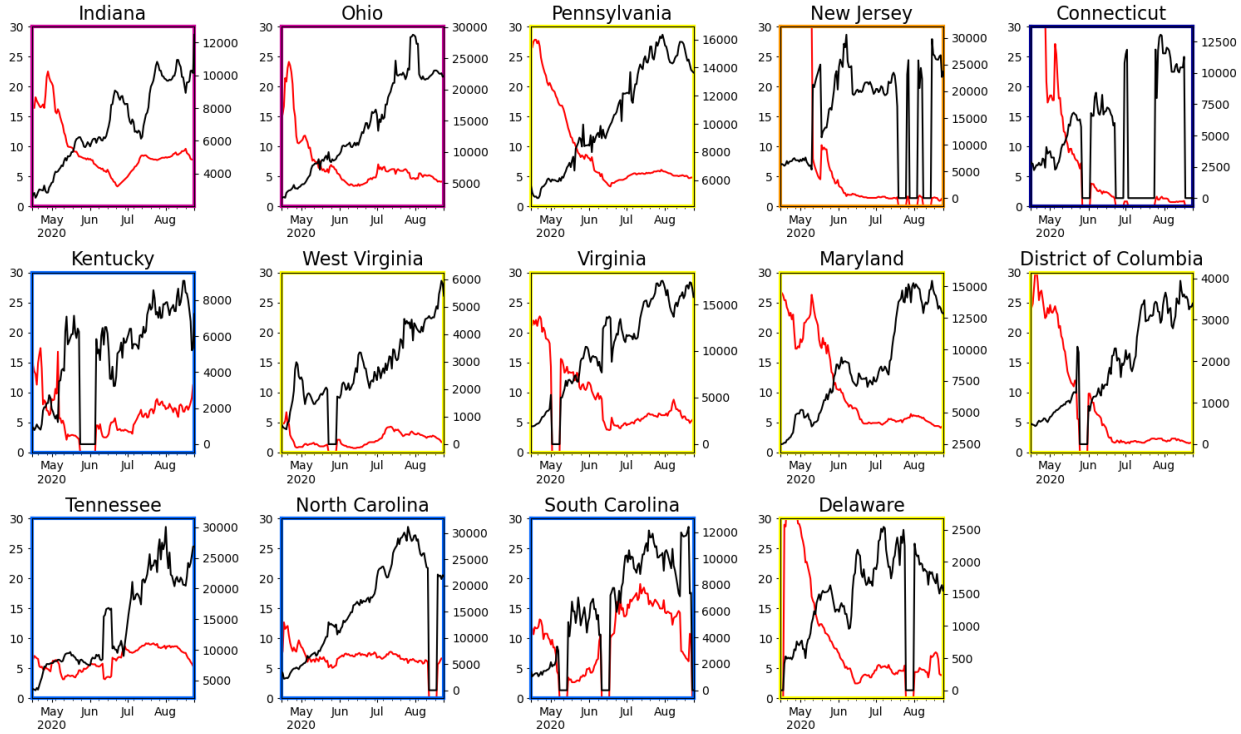
Other State Comparisons

Case Rate per 100K population



- Most states experiencing declines or plateaus in last couple weeks
- DE and NC showing some rebounds
- TN declining but still quite high

Tests per Day and Test Positivity

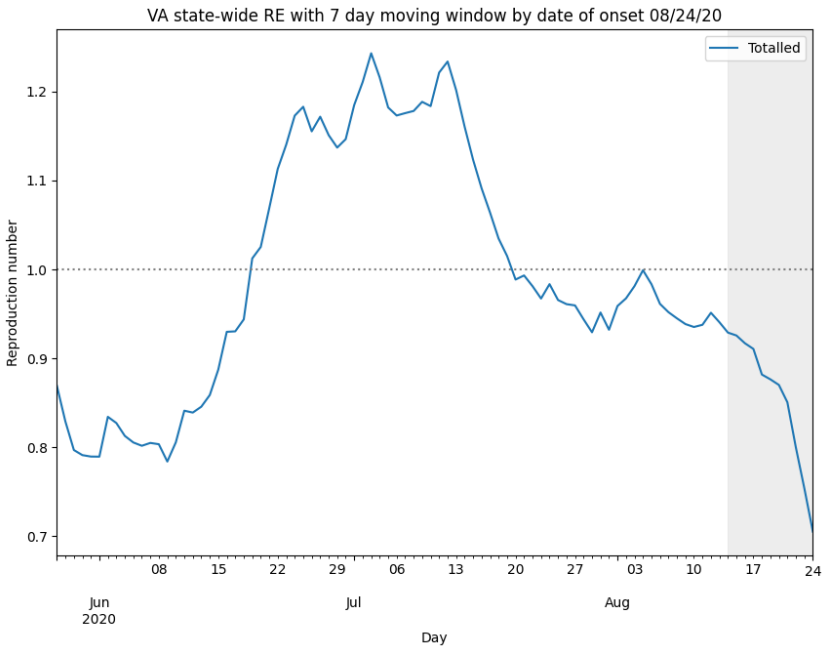


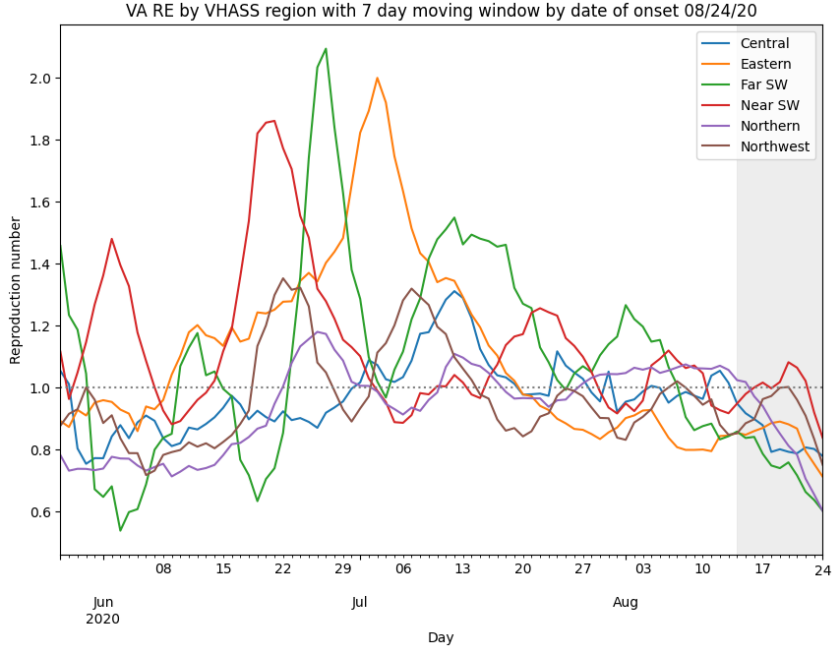
- Good signs as test positivity shows recent decline in most states
- Testing volumes plateau, potentially due to long turnaround times and individuals deciding to not seek a test

Estimating Daily Reproductive Number

August 15th Estimates

Region	Current R_e	Diff Last Week
State-wide	0.926	-0.006
Central	0.917	-0.024
Eastern	0.848	0.057
Far SW	0.838	-0.013
Near SW	0.979	-0.063
Northern	1.018	-0.001
Northwest	0.885	-0.094





Methodology

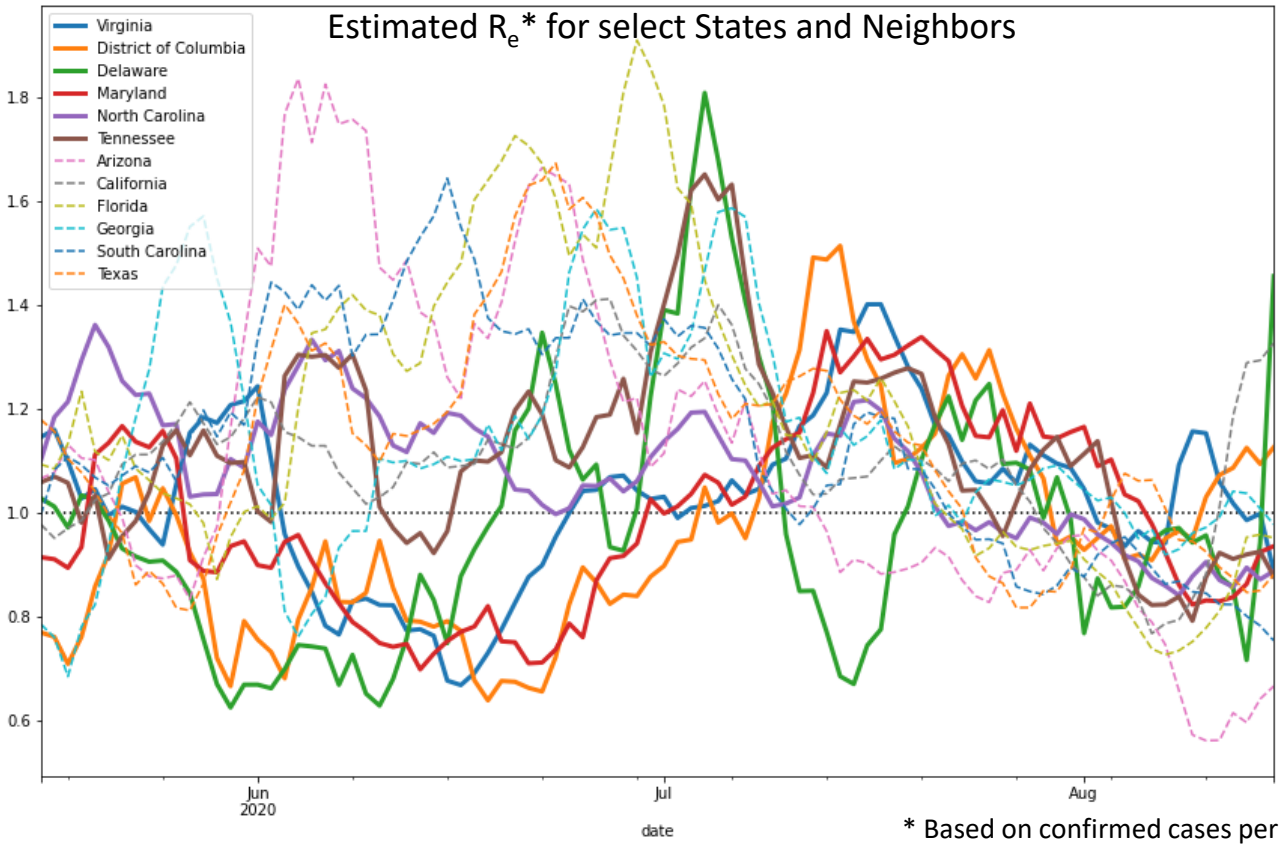
- Wallinga-Teunis method (EpiEstim[1]) for cases by date of onset
- Serial interval: 6 days (2 day std dev)
- Recent estimates may be unstable due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

Other State Comparisons

Reproductive Number (R_e) has downward trend across hotspots and Virginia's neighbors

- Most of the national hotspots such as AZ, CA, TX, FL are now below 1
- Virginia and neighboring states are mostly at and below 1



VA and neighbors continued decline

* Based on confirmed cases per day

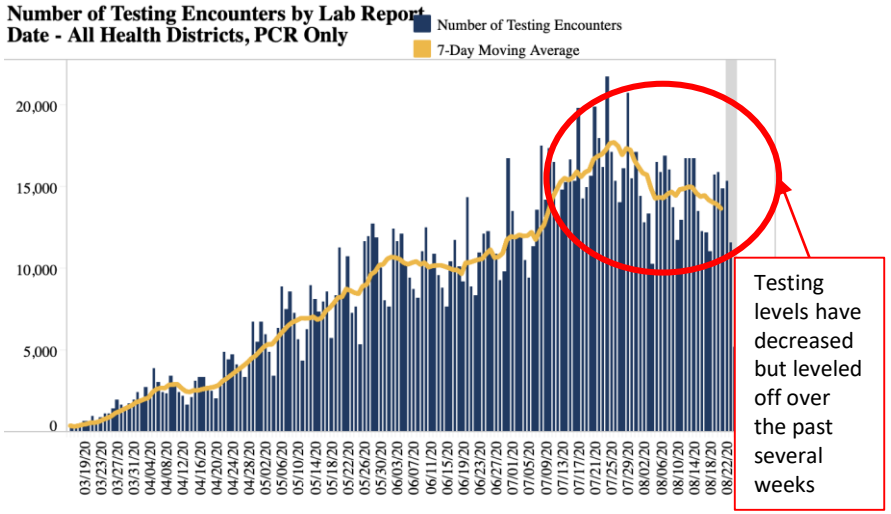
Changes in Case Detection

Days to Diagnosis dropped but rebounding

- Mid March to Late April = 8.4 days
- Late April to Late May = 5.8 days
- Late May to Late June = 5.6 days
- Early July to mid Aug = 5.8 days

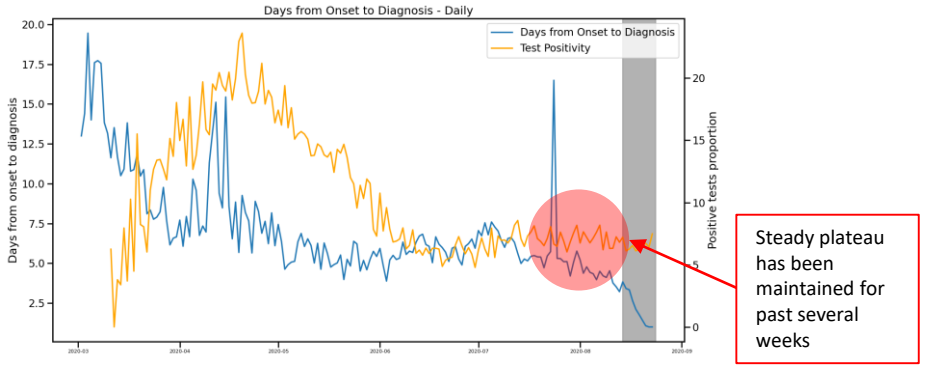
Returning to lower levels

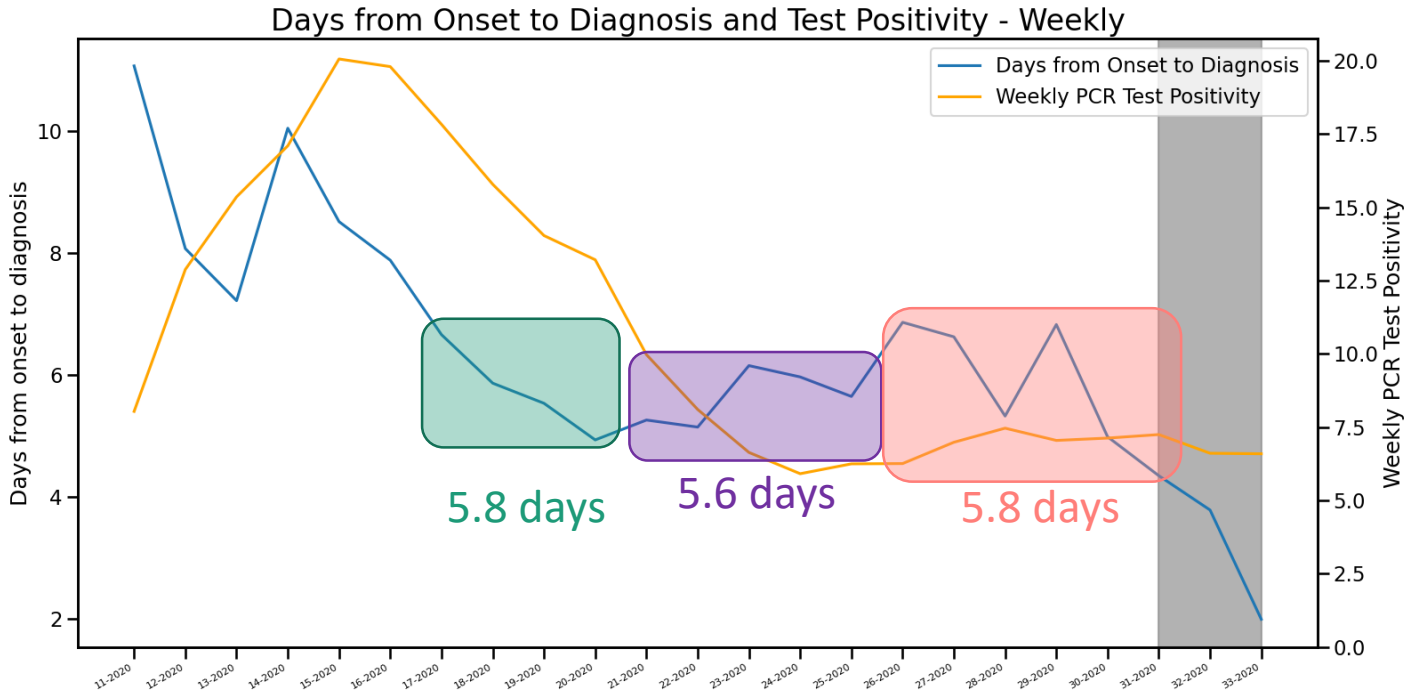
Testing Encounters and test positivity have steadied and increased



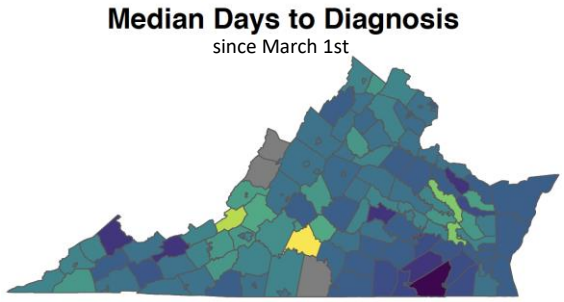
Accessed 10pm August 25, 2020
https://www.vdh.virginia.gov/coronavirus/

Test positivity vs. Onset to Diagnosis

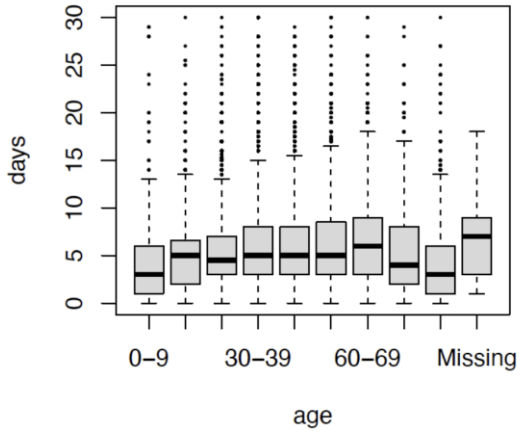




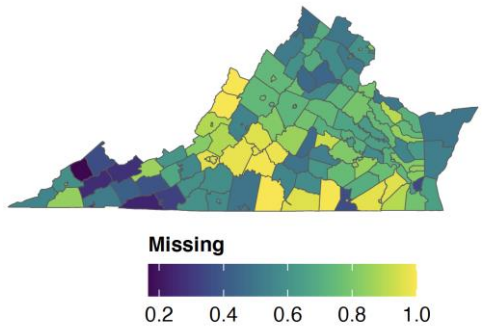
Changes in Case Detection – By District/Age



Slight variations by age group
(0-9, 70-79 and 80-89 have lower medians)
No significant variation by severity (hosp./ICU)



Only ~35% records have entries

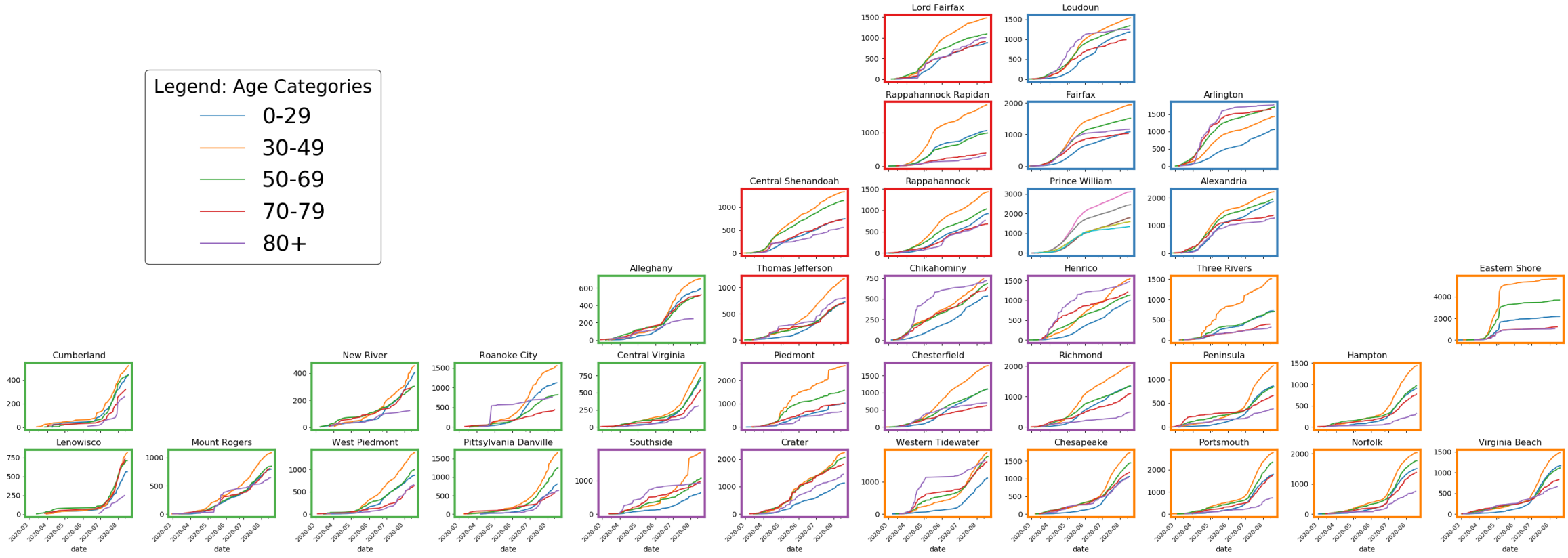


Age-Specific Attack Rates (per 100K)

Cumulative Age-specific Attack Rates (per 100k)

- Younger age groups outpace older in many districts

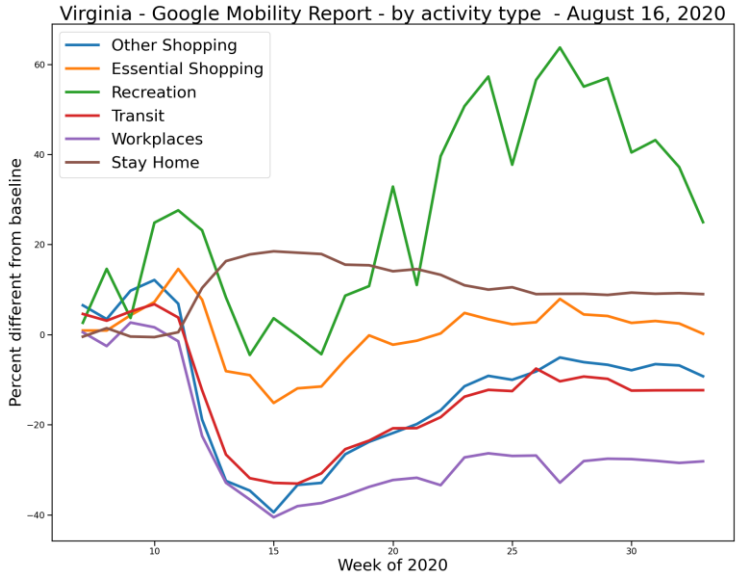
Age-adjusted Cumulative Prevelance Rate Per 100k District Population

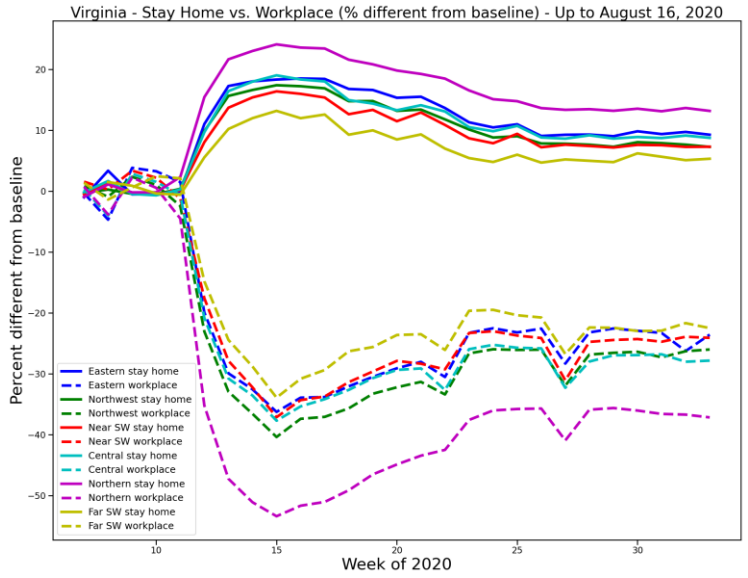


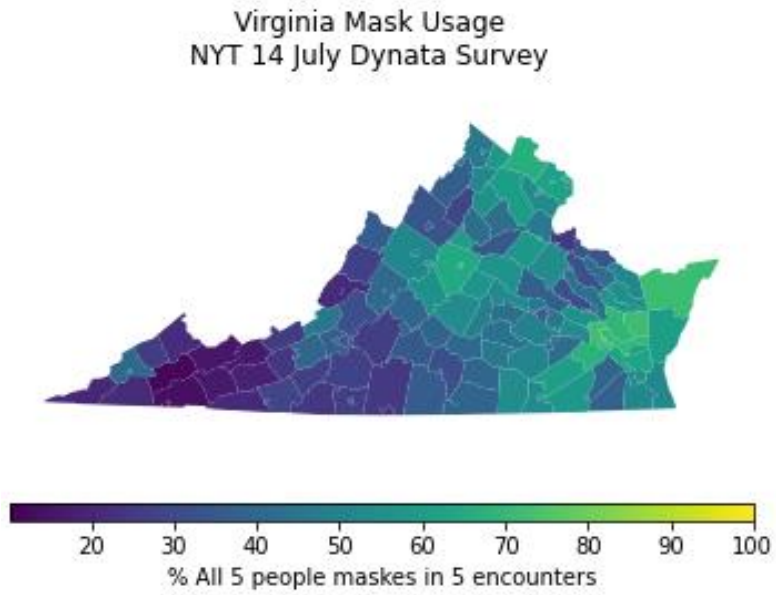
Estimating Effects of Social Distancing

Google Mobility data shows continued slow rebound (as of July 26th)
https://www.google.com/covid19/mobility/

- Continued slow reduction of those staying at home. Workplace levels remain low.
  - Urban/Rural variations in levels (e.g., Northern vs Far SW)
- Essential shopping back to baseline. Other shopping/transit trending towards baseline.
- Parks and recreation significantly higher than baseline (seasonal effects).
- Mask usage not evenly distributed, higher in Northern central, lower Southwest and Richmond area







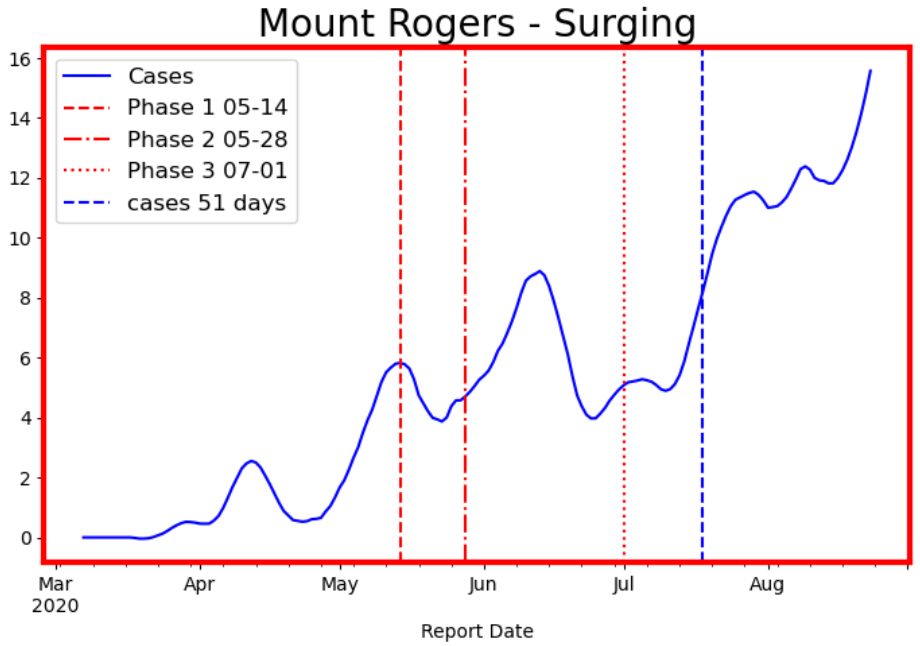
Surges Fading

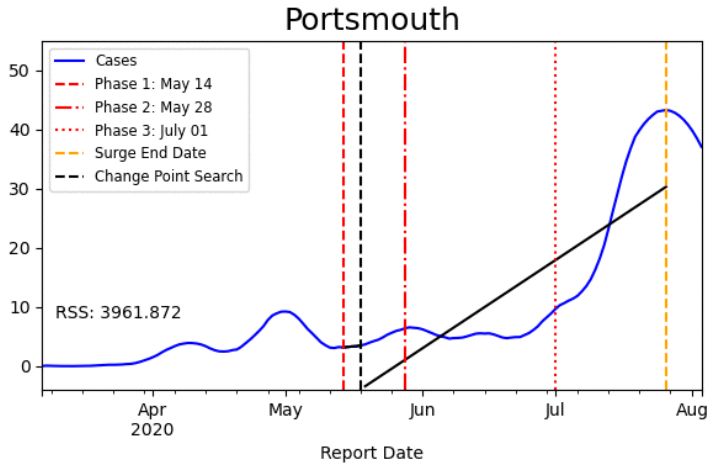
Fading Resurgence: Recent surges now decreasing

- Most districts have slowed and started to decline, however, some continue to have sustained rapid growth

Surge Detection:

- Using “hockey stick” fit to assess timing of surge
- **Surging**: Best fits with slope greater than 2.5 cases / 100K / week
- **Slowing**: Surge with a peak in last 10 days
- **Ended**: Surge has peaked more than 10 days ago without rebound





Only 1 district being tracked (compared to 8 last week)

In: --No new surges--

Out: Central Virginia, Chickahominy, Crater, Lenowisco, Pittsylvania-Danville, Southside, West Piedmont

District Trajectories

Hockey stick fit used to describe recent growth patterns

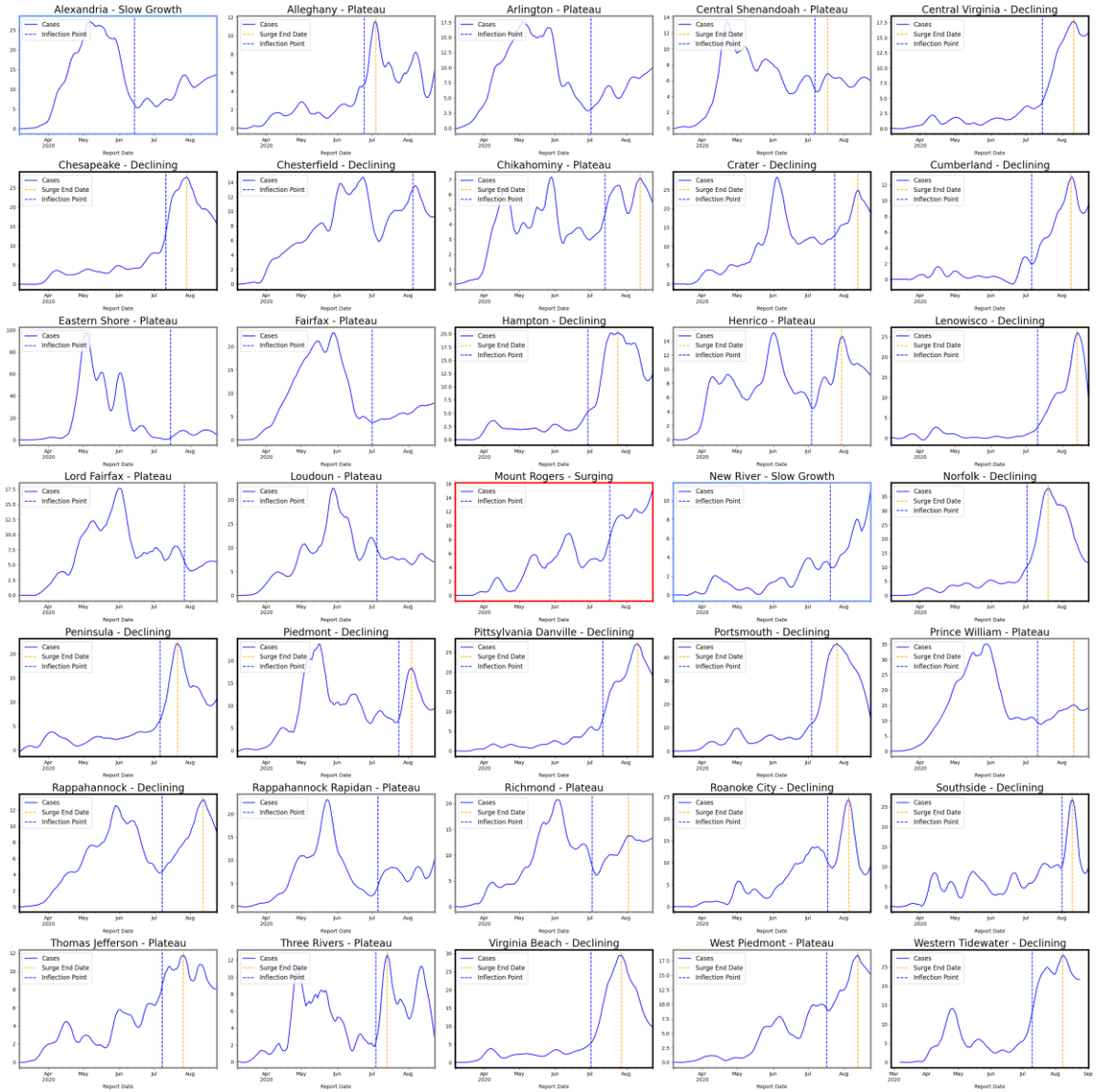
Declining: Sustained decreases following a recent peak

Plateau: Steady level or mixed increases and decreases

Slow Growth: Sustained growth not rapid enough to be considered a Surge

In Surge: Currently experiencing sustained rapid growth

Status	# Districts
Declining	17
Plateau	15
Slow Growth	2
In Surge	1



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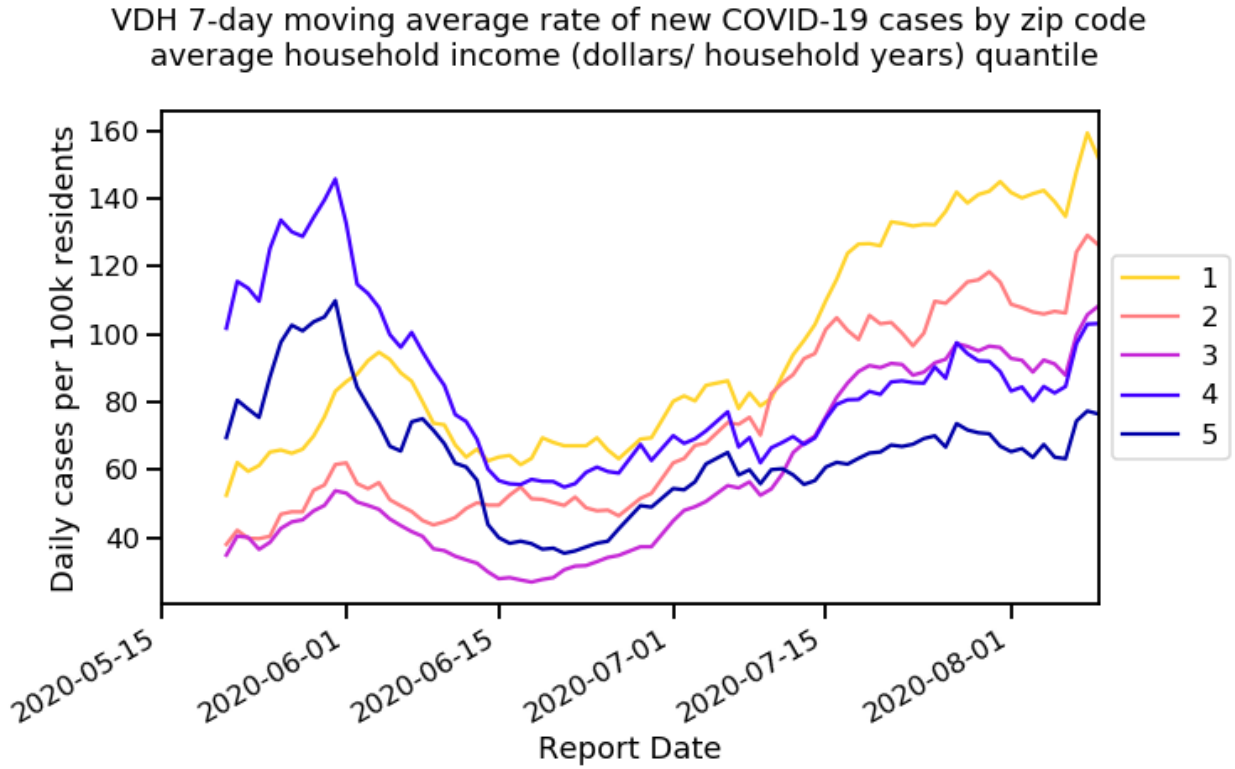
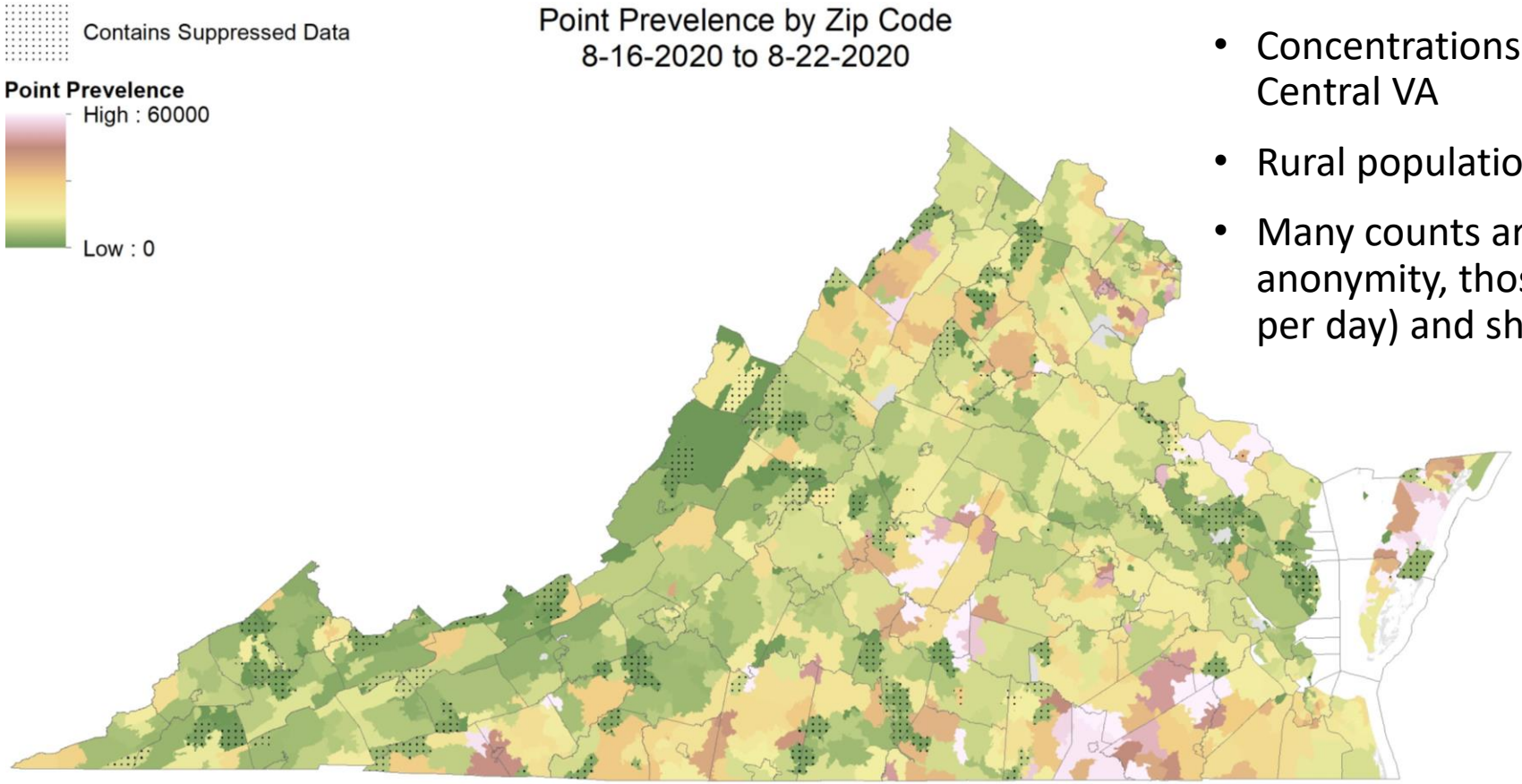
Impact across Density and Income



Lower 20% income zip codes now reporting highest case rates

Can see the evolution from denser and wealthier zip codes to poorer and less dense zip codes

Zip-code level weekly Case Rate (per 100K)



Cases in the last week by zip-code

- Concentrations of prevalence along southern border, Central VA
- Rural populations showing high case rates
- Many counts are low and suppressed to protect anonymity, those are assumed to be 1 case (per zip per day) and shown with the speckled pattern

Model Update – Adaptive Fitting

Adaptive Fitting Approach

Each county fit precisely, with recent trends used for future projection

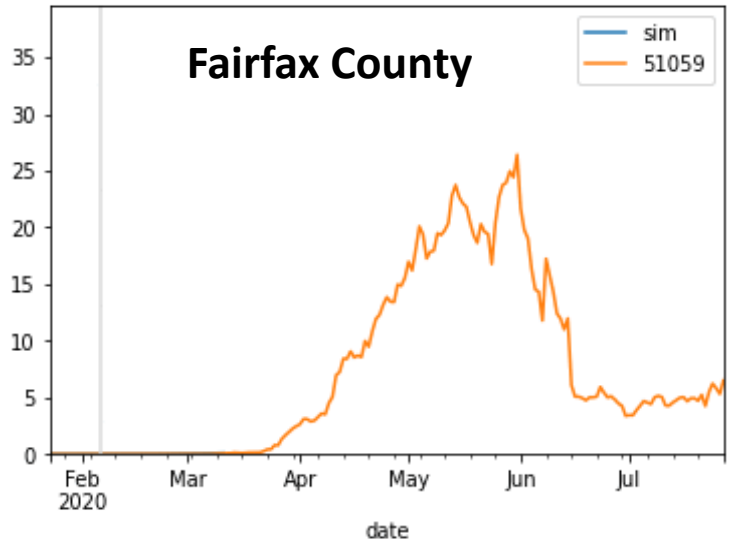
- Allows history to be precisely captured, and used to guide bounds on projections

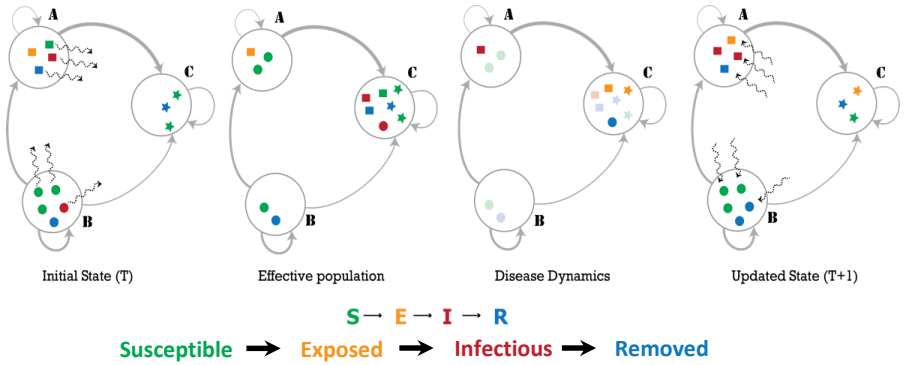
Model: An alternative use of the same meta-population model, PatchSim

- Allows for future "what-if" Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions
- Uses steady 1 case per 10M population per day external seeding





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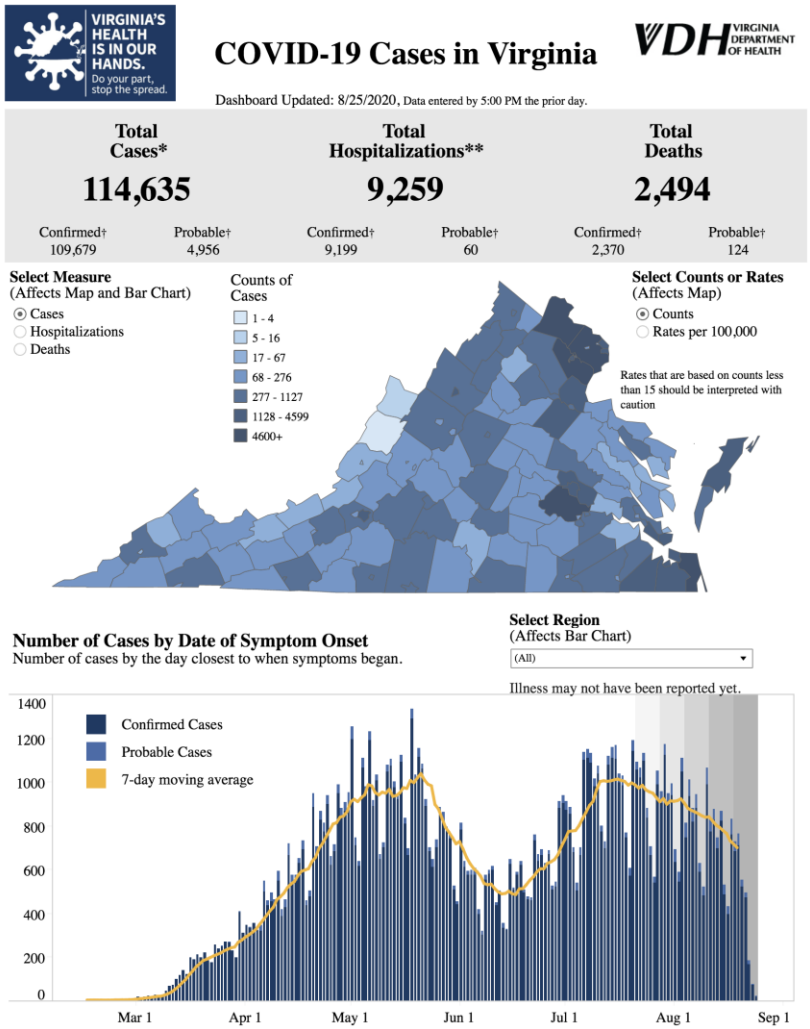
Calibration Approach

- **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting
- **Calibration:** fit model to observed data
  - Tune transmissibility across ranges of:
    - Duration of incubation (5-9 days), infectiousness (3-7 days)
    - Undocumented case rate (2x to 15x)
    - Detection delay: exposure to confirmation (4-12 days)
  - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak
- **Project:** future cases and outcomes using the most recent parameters with constraints learned from the history of the fit parameters
  - Mean trend from last 7 days used, adjusted by variances in the previous 3 weeks
  - 1 week interpolation to smooth transitions in rapidly changing trajectories
  - Particles with high error or variance filtered out



Accessed 9am August 26, 2020
https://www.vdh.virginia.gov/coronavirus/

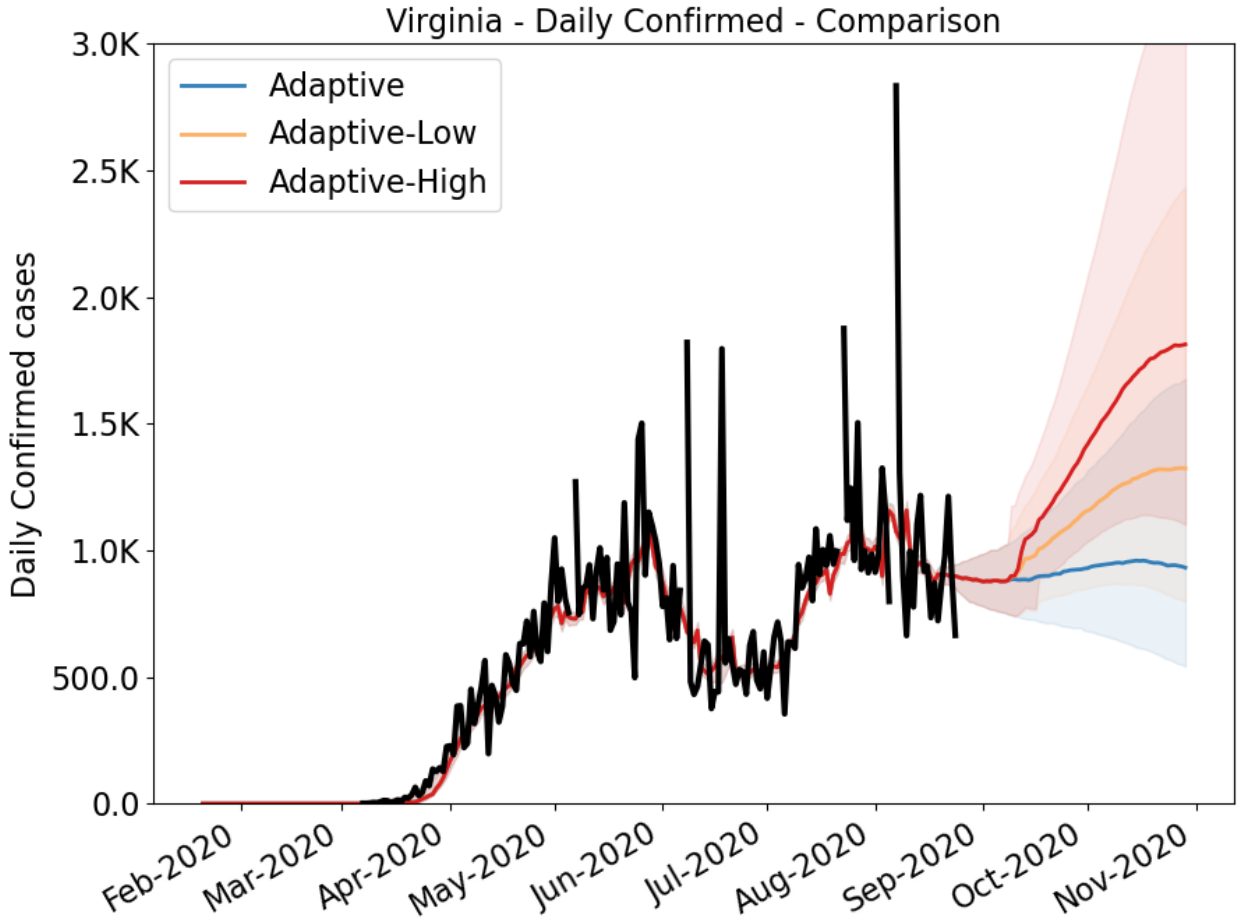
Scenarios – Seasonal Effects

- Societal changes in the coming weeks may lead to an increase in transmission rates
  - Start of in-person school
  - Changes to workplace attendance
  - Seasonal impact of weather patterns
- Three scenarios provided to capture possible trajectories related to these changes starting following Labor Day, Sept 7th, 2020
  - Adaptive: No change from base projection
  - Adaptive-Low: 10% increase in transmission starting Sept 8th, 2020
  - Adaptive-High: 20% increase in transmission starting Sept 8th, 2020

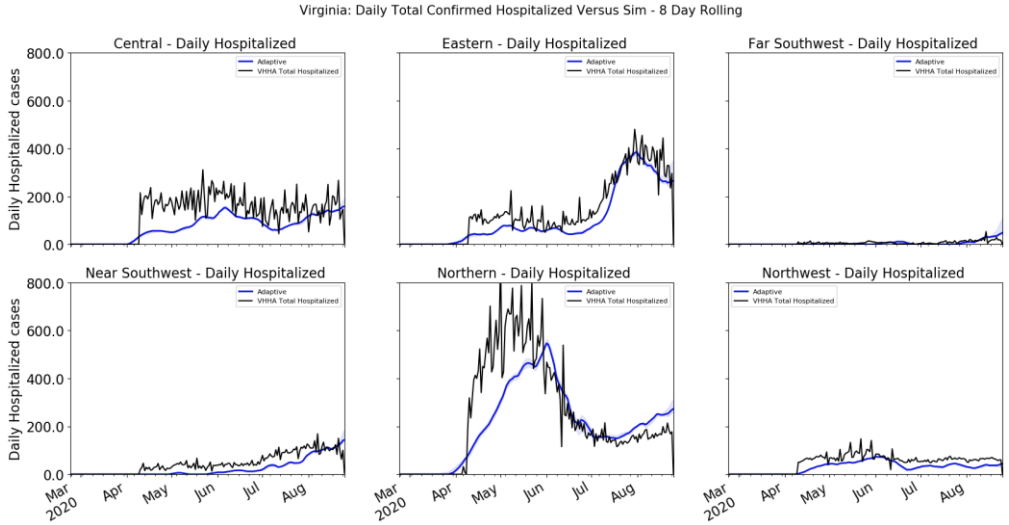
Model Results

Outcome Projections

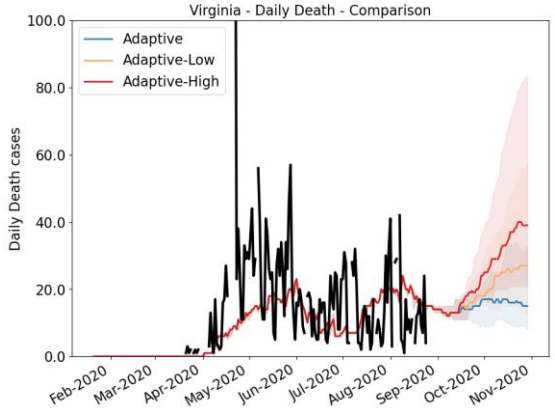
Confirmed cases



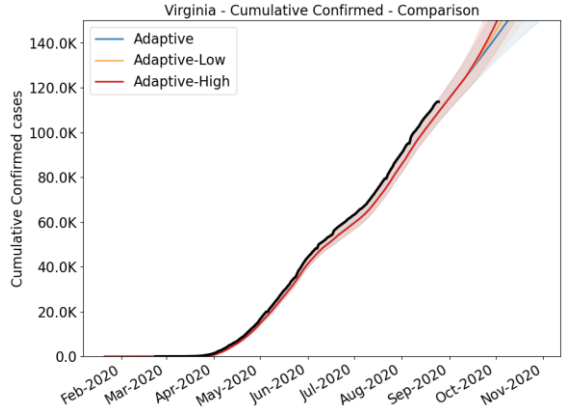
Estimated Hospital Occupancy



Daily Deaths



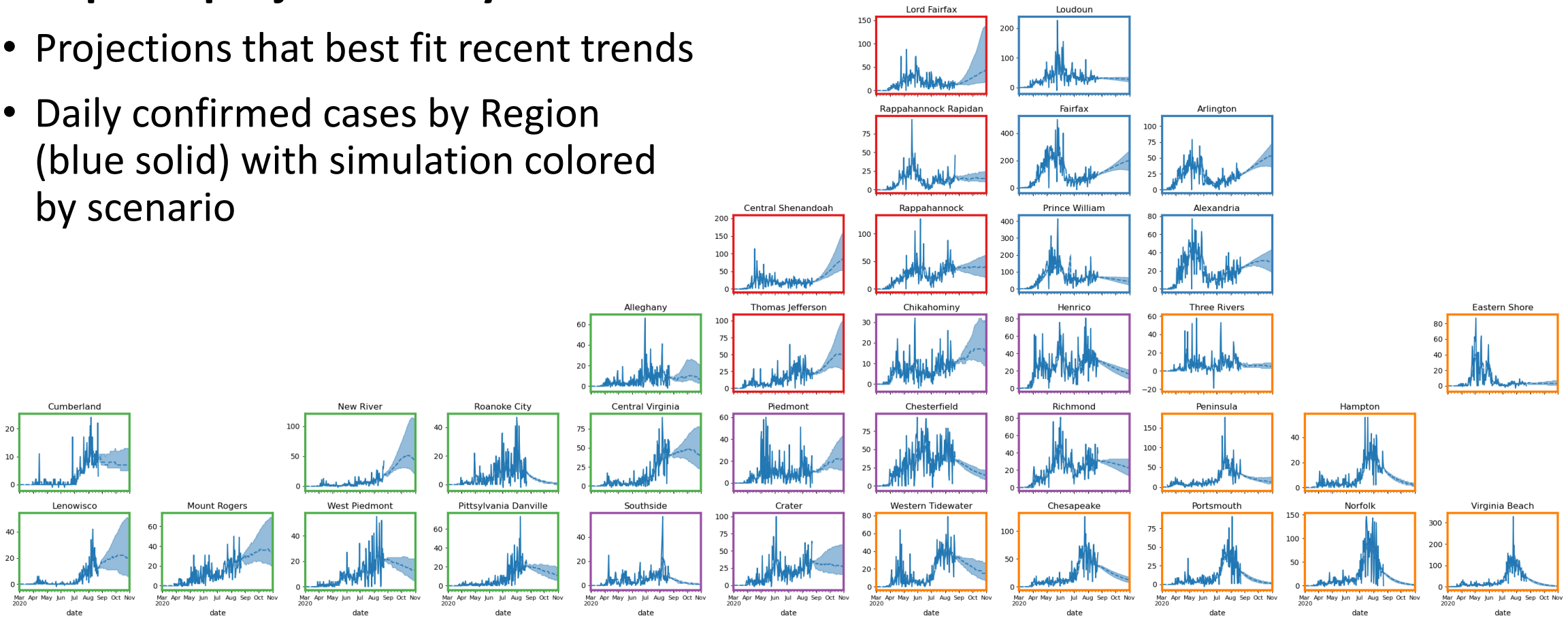
Cumulative Confirmed cases



District Level Projections: Adaptive

Adaptive projections by District

- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



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District Level Projections: Adaptive-Low

Adaptive projections by District

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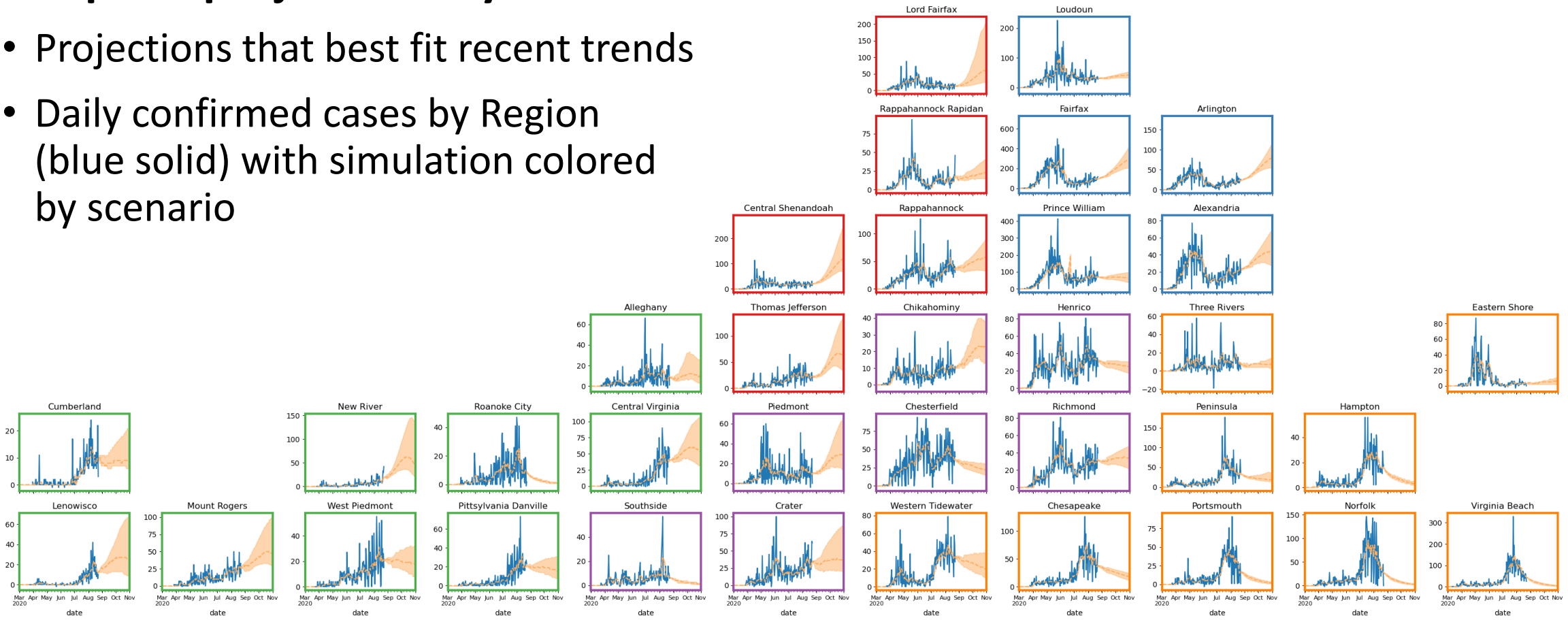

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District Level Projections: Adaptive-High

Adaptive projections by District

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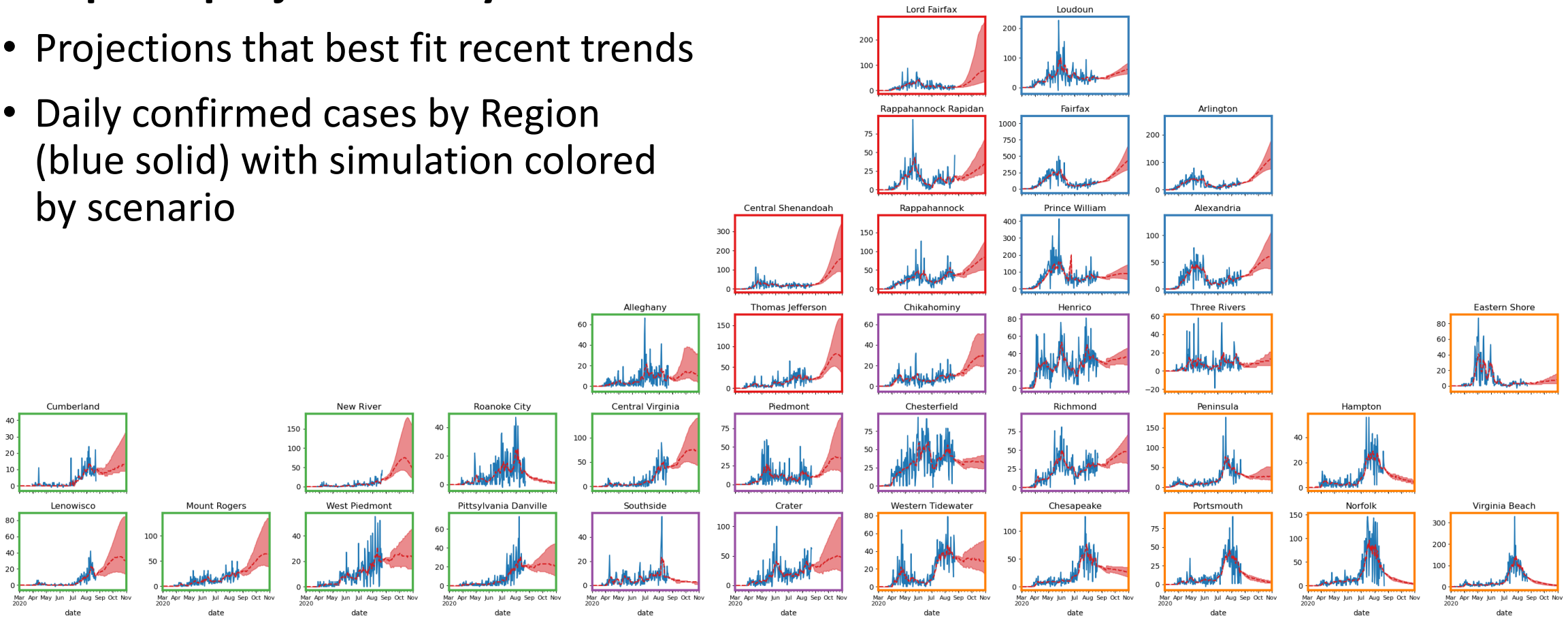
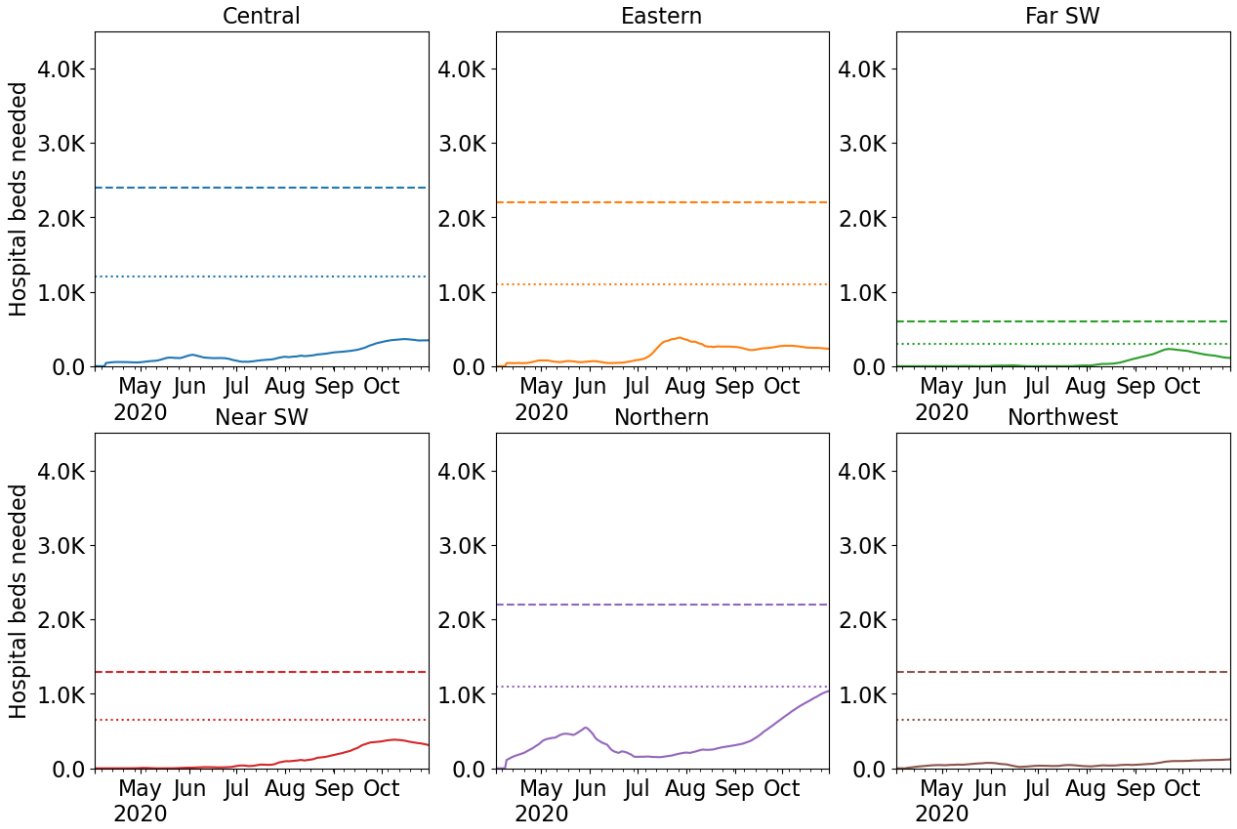


Hospital Demand and Capacity by Region

Capacities by Region – Adaptive-High

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds



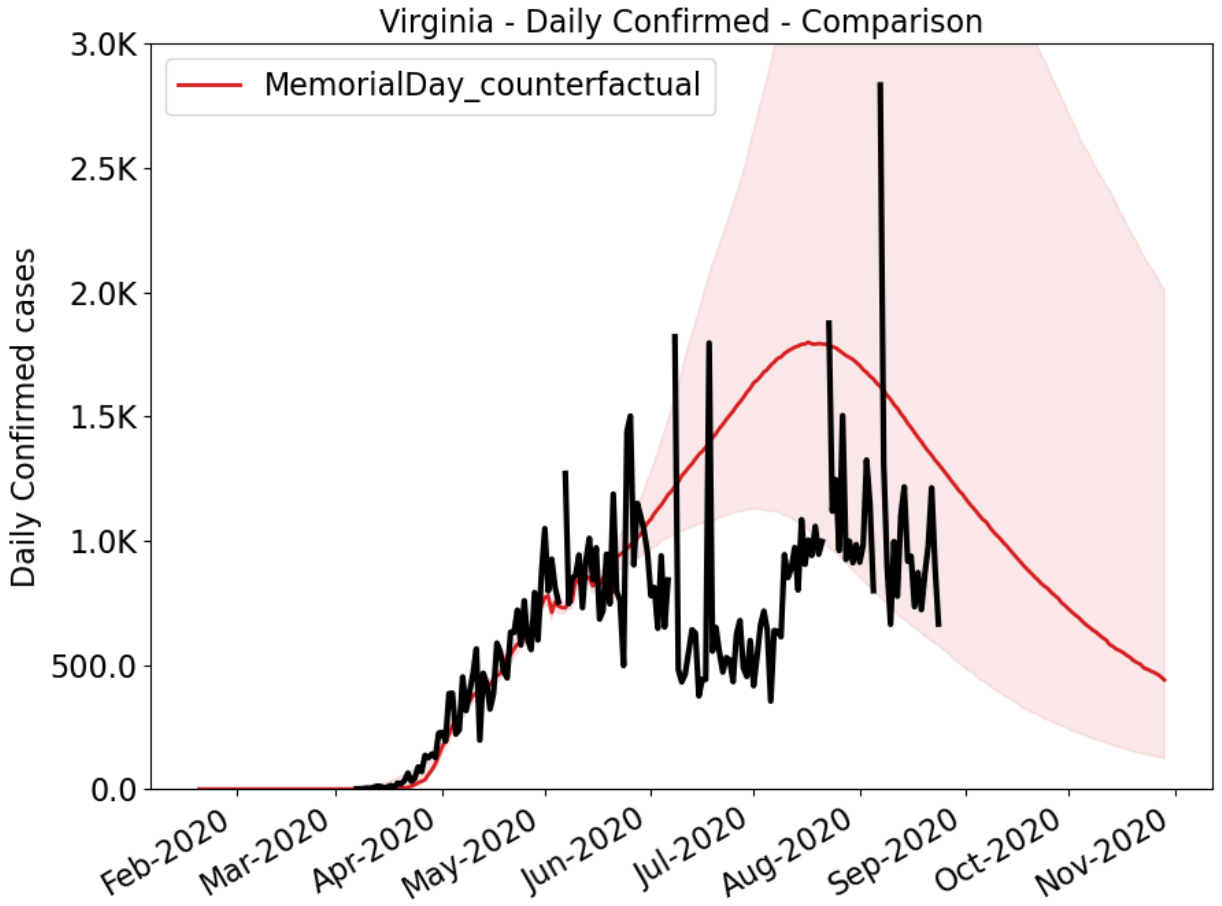
Week Ending	Adaptive	Adaptive-High
8/23/20	6,342	6,342
8/30/20	6,254	6,254
9/6/20	6,158	6,158
9/13/20	6,168	6,237
9/20/20	6,225	7,482
9/27/20	6,348	8,498
10/4/20	6,482	9,600
10/11/20	6,606	10,674
10/18/20	6,680	11,663
10/25/20	6,661	12,318
11/1/20	6,552	12,648
11/8/20	6,358	12,684

Based on Adaptive-High scenario

- No regions forecast to exceed capacity
- Northern approaching capacity at the beginning of November

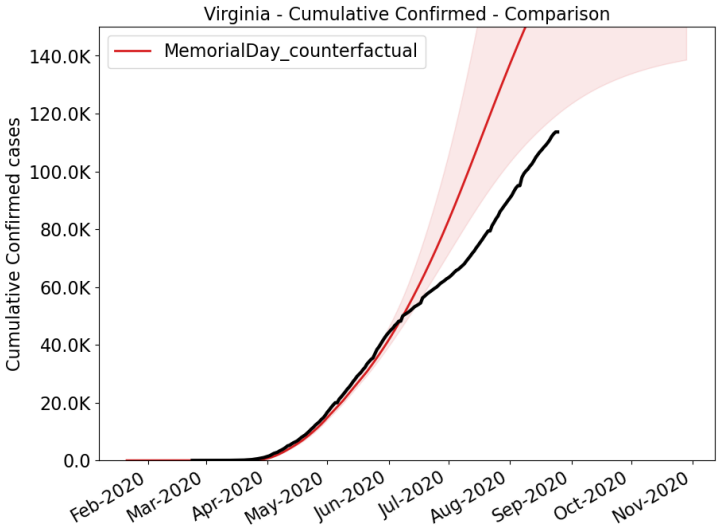
* Assumes average length of stay of 8 days

Counter-factual Analysis



"What If" the whole Summer was like late Spring?

- Scenario where the trends present up to Memorial Day week had persisted throughout the summer
- Over 62K cases averted



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Even without perfect projections, we can confidently draw conclusions:

- **Surges are fading and incidence is declining.**
- Majority of districts are plateauing or declining
- Projections are mixed across a range of slow-growth, plateaus, and declines
- Recent model updates:
  - Adaptive Fitting projection remains, slight adjustments to projection filtering
  - Seasonal effects scenarios for planning for end of summer changes
- The situation is changing rapidly. Models will be updated regularly.

References

Venkatramanan, S., et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints." *PLoS computational biology* 15.9 (2019): e1007111.

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Biocomplexity Institute. COVID-19 Surveillance Dashboard. https://nssac.bii.virginia.edu/covid-19/dashboard/

Google. COVID-19 community mobility reports. https://www.google.com/covid19/mobility/

Cuebiq: COVID-19 Mobility insights. https://www.cuebiq.com/visitation-insights-covid19/

Biocomplexity page for data and other resources related to COVID-19: https://covid19.biocomplexity.virginia.edu/

Questions?

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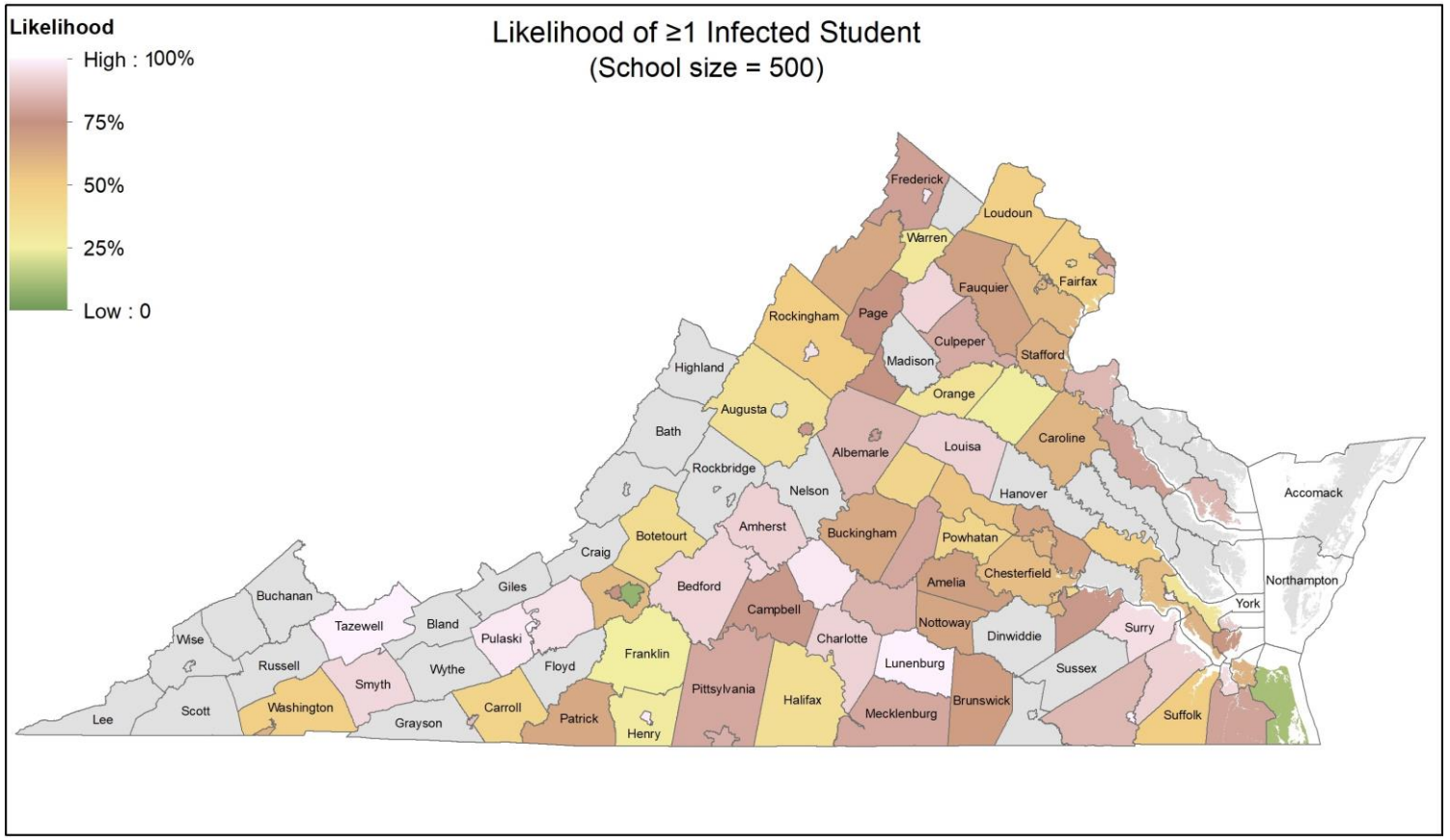
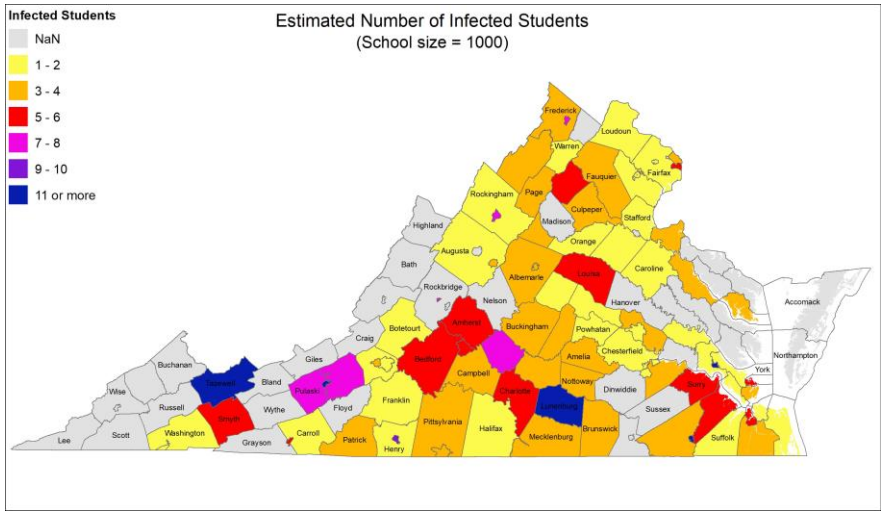
Supplemental Slides

School Age Prevalence



- Using school-age incidence in the last week, we estimate the likelihood any collection of school age kids in a school size of 500 will have at least one infection
- Assume that for each confirmed case there are 6 other undetected infections



Recent Parameter Validation

New York State announced sero-prevalence survey results on May 2nd

- 15,000 antibody tests conducted randomly through the state at grocery stores
- **Total Attack Rate**: 12.3%

Estimation of undetected infections

- Total infections in NY = 2.46M, total of 300K confirmed cases
- Confirmed case detection = 12% of infections (close to 15% used in model)

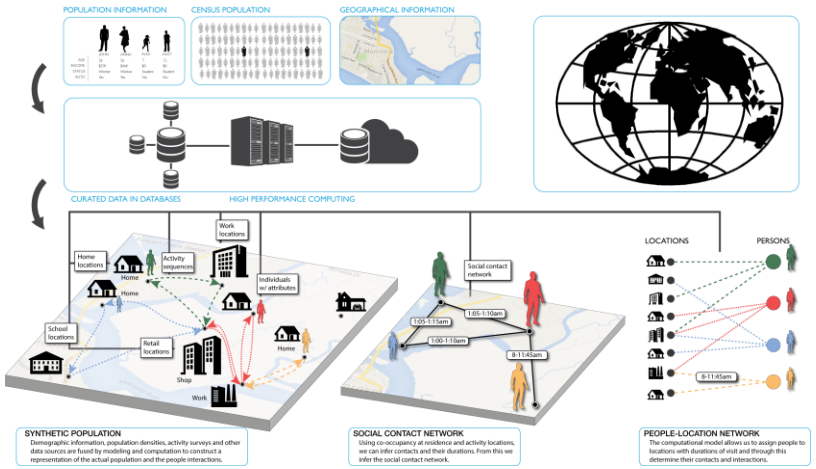
Estimation of hospitalizations from infections

- Total infections in NY = 2.46M, total of 66K hospitalizations
- Hospitalizations = 2.7% of infections (close to 2.25% used in model)

Agent-based Model (ABM)

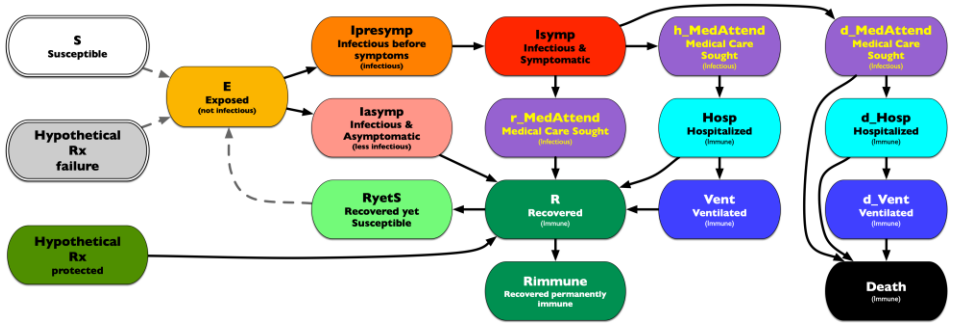
EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing



Synthetic Population

- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations



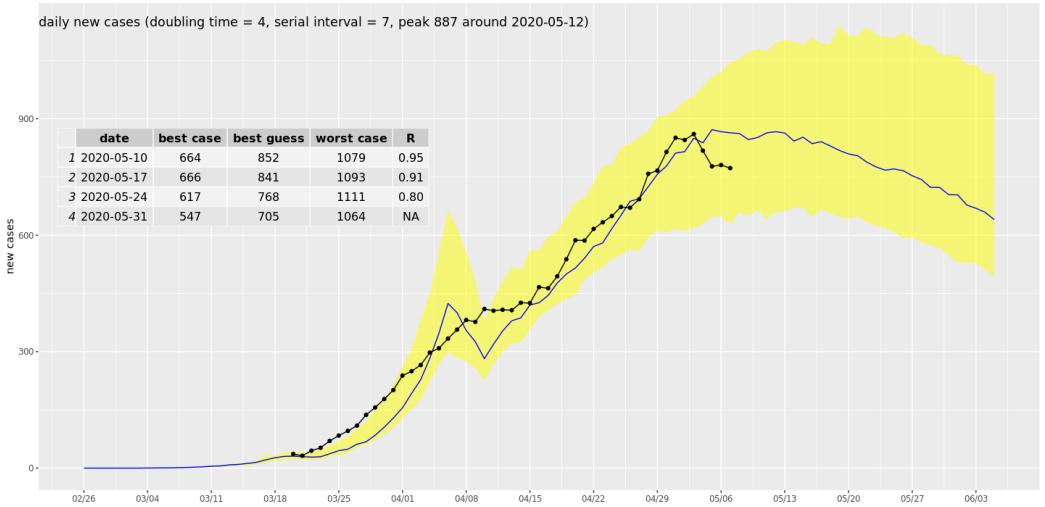
Detailed Disease Course of COVID-19

- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments

ABM Social Distancing Rebound Study Design

Study of ”Stay Home” policy adherence

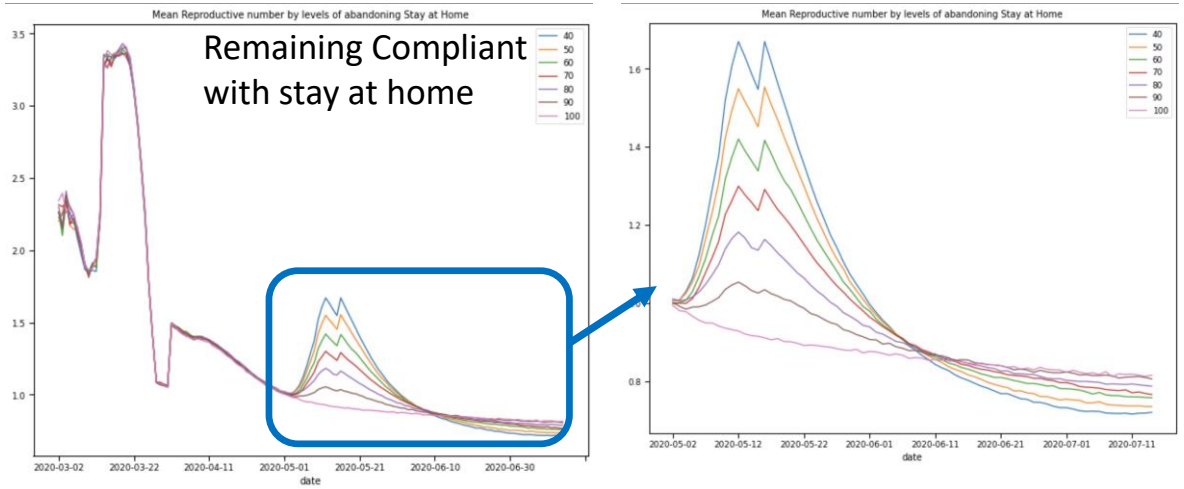
- Calibration to current state in epidemic
- Implement “release” of different proportions of people from ”staying at home”



	date	best case	best guess	worst case	R
1	2020-05-10	664	852	1079	0.95
2	2020-05-17	666	841	1093	0.91
3	2020-05-24	617	768	1111	0.80
4	2020-05-31	547	705	1064	NA

Calibration to Current State

- Adjust transmission and adherence to current policies to current observations
- For Virginia, with same seeding approach as PatchSim

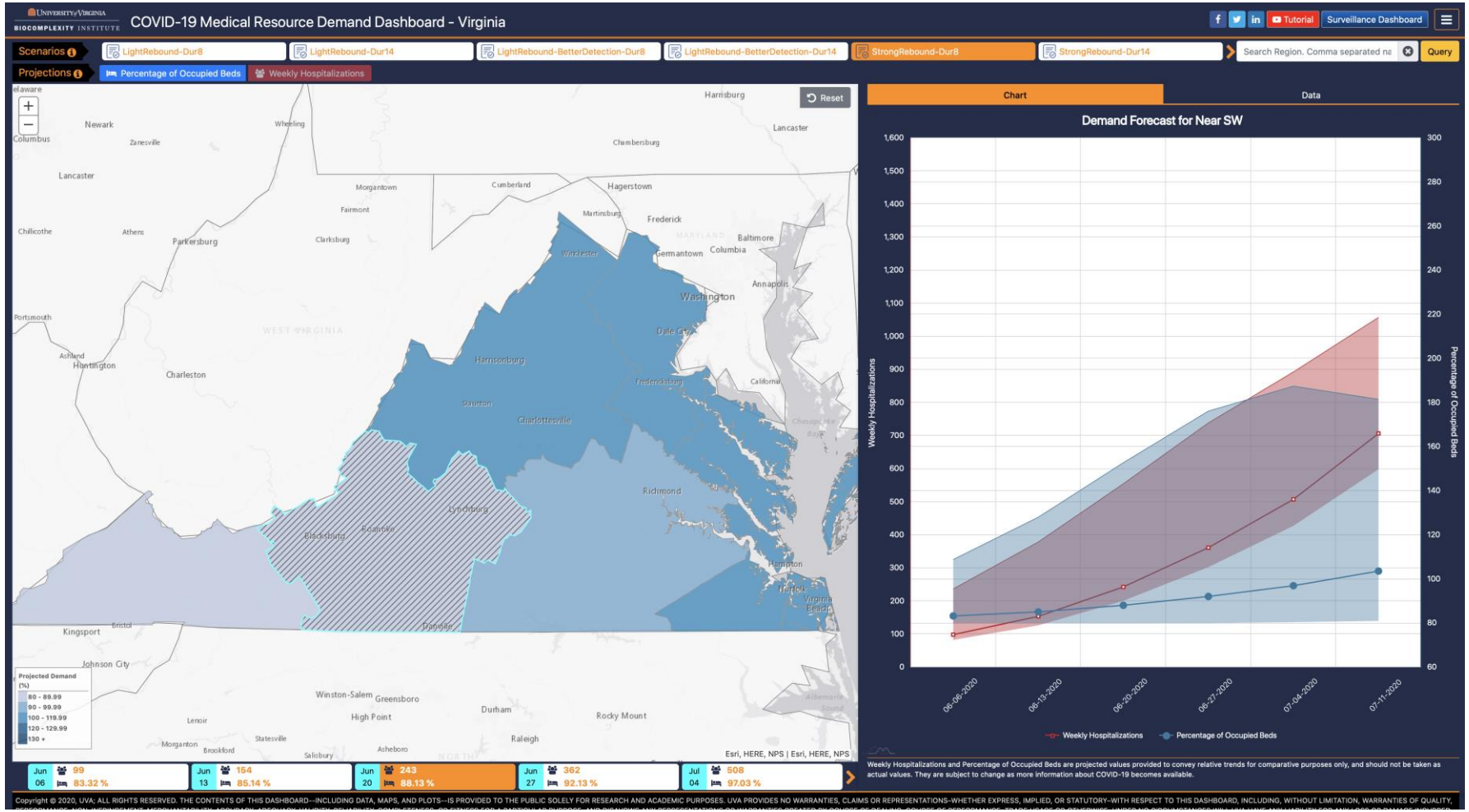


Impacts on Reproductive number with release

- After release, spike in transmission driven by additional interactions at work, retail, and other
- At 25% release (70-80% remain compliant)
- Translates to 15% increase in transmission, which represents a 1/6th return to pre-pandemic levels

Medical Resource Demand Dashboard

https://nssac.bii.virginia.edu/covid-19/vmrddash/



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